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GUIDELINES FOR DESIGN TO UNIT PRODUCTION COST (DTUPC)

Clifton T. Trigg

Army Electronics Command
Fort Monmouth, New Jersey

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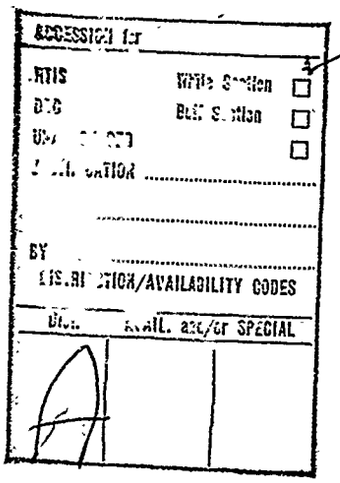

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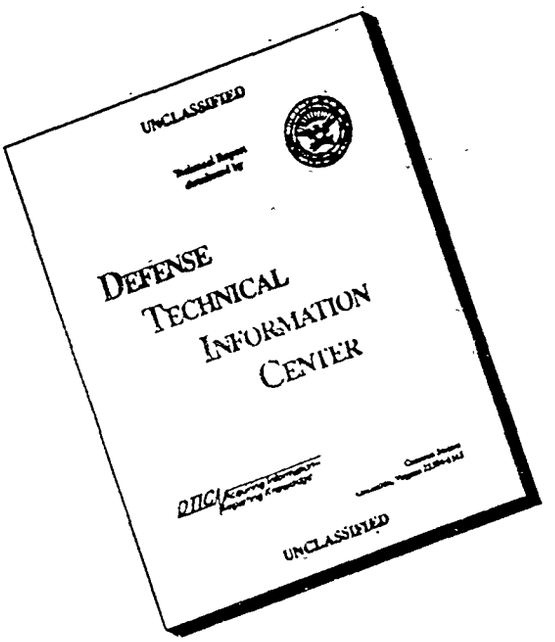

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GUIDELINES FOR DESIGN TO UNIT PRODUCTION COST (DTUPC)

by

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OCTOBER 1973

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The introduction of DOD Directive 5000.1, AR 1000-1 and the new materiel acquisition guidelines has been followed by numerous directives, policy statements, and similar papers that philosophically address the issue of Design to Unit Production Cost (DTUPC). The guidance on DTUPC has been evolutionary in character, and therefore, this report represents a synopsis of the more important salient points of DTUPC implementation. As such it describes the DTUPC, explores the criteria of when it should be applied, suggests methods for development of the DTUPC, and provides guidance for the establishment of tracking procedures.

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TABLE OF CONTENTS

FIGURES

Introduction.

The purpose of this paper is to provide to managerial personnel a synopsis of much of the "Design-to" material that has emanated from various elements of the Army over the recent past. It is not intended to be a procedural text providing step-by-step instructions to project level personnel. Such material will be forthcoming as the concepts of "Design-to" become more definitive.

A survey of the recent literature would indicate that "Design-to" and its implementation is at present evolutionary in character. Therefore, this paper is an attempt, at this point in time, to provide a short ready reference, delineating definitions, extent of existing policy, local decision prerogatives, and approaches to the implementation of the New Materiel Acquistion Guidelines.

What is "Design to Unit Production Costs?"

The "New Materiel Acquisition Guidelines" define the Design to Unit Production Cost as that unit cost, established prior to the development of an item, which represents the Government's cost goal to guide design and control program costs. It is the projected unit cost to the Government to acquire a production item based on an economical level of production.

The underlined elements of the above definition highlight the critical points that must be considered in deriving the "Design to Unit Production Cost" (DTUPC). It is a unit cost which will be experienced sometime in the future. In a broad view, it represents the value the Government places on the accomplishment of certain mission objectives through materiel acquisition. If the DTUPC is established at local levels and is presented in a Determination and Findings (D&F) and later in a Request for Proposal (RFP), it must be considered as inviolate by contracting and technical personnel. Authority to alter the DTUPC resides at higher headquarters, the level of which will be determined on an individual basis for each program.

This sounds a bit frightening and may lead to a tendency to establish a "safe" DTUPC at a higher dollar value than the estimator truly feels the item should cost. This may work for awhile, but a high DTUPC could kill the program during the review cycle or could result in embarrassment when proposals are received. It must be remembered that the AMC Basic Procurement guidance states, that in the evaluation of the cost aspects of a proposal, the proposed "design to" cost is weighted heavier than the development costs. Also, the cost proposal, in toto, is to be weighted equally to the technical proposal. If the proposal "design to" costs are found to be substantially lower than that stated in the RFP, critical evaluation of the difference must be conducted and reconciled accordingly.

On the other hand, if the DTUPC in the RFP is too low and all proposals come in with either higher values or unacceptable performance predictions, resolution will be required at higher headquarters. It therefore, is best to develop the DTUPC as carefully as possible, be extremely definitive, and approach it from as many different methodologies and sources as practicable.

The DTUPC should represent a unit cost that includes the cost elements that are included in the AMC Key Cost Definition for "Flyaway Cost". This definition limits the costs to be considered to only PEMA funds for Non-recurring and Recurring Investment on the mission equipment. It does not include PEP (RDT&E funded), spares, repair parts, training, or documentation.

Mission equipment is the black box or configuration of black boxes that are hardware in nature and are required to fulfill TO&E, BOI, and/or AAO requirements. The DTUPC for the mission equipment should be stated in a specific year dollars, e.g., FY 73, and provision stated in the RFP that the DTUPC will be adjusted in accordance with some inflation index. The specific index can be set forth, although this will probably become a point of negotiation. Even though this brings the DTUPC for a future buy back to todays price, it doesn't completely eliminate the problems of forecasting. "Design-to" type contracts will normally be of cost reimbursable type having incentive and/or award fee pools involved. The use of an economic index is to allow for adjustment of the DTUPC to reflect any inflationary trends. The economic index does not reflect a lowering of price due to technological maturity. By technological maturity, is meant that where specific components, parts, or techniques may be unique and high priced when originally introduced, the price will drop as they become less unique and produced in greater quantities for wider use. Today or tomorrow's technology (possibly unique) might be viewed to result in certain costs today, but the DTUPC will have to reflect what the item and attendant technology (possibly mature) will cost several years from now when the item is produced. Another way of saying this is: What would it cost today if future technology were available? If this is not considered, the incentive/award fee pool may become a bonus not for effort, but for extended time. More will be said on this later.

When Should the "DTUPC" Be Applied?

The development life cycle depicted in most guidance documents shows items progressing from exploratory development (6.2), through advanced development (6.3), to engineering development (6.4). The latest regulation concerning design-to is AR 1000-1, and it indicates that design-to criteria should be applied during the validation phase (AD 6.3) and no later than full scale development (ED 6.4). However, in the real world the full development string is not always so clearly present. The Required Operational Capability (ROC) may trigger a 6.2, 6.3 or 6.4 effort. If it triggers a 6.4 effort, there may or may not have been a compatible earlier effort on which to base an estimate.

In any event, the funding category that a program is in should reflect the degree of knowledge and confidence in developing an item. If it doesn't, the program is in the wrong category. Assuming that knowledge and confidence increase with the advancement of funding category, it is also reasonable to conclude that confidence in a DTUPC should follow a similar pattern. This might be labelled the degree of softness of the DTUPC, and should be accompanied with a degree of softness in the "goals" set forth by bands of performance.

The terms softness and bands have now been introduced and should be put in better perspective. Softness and Bands must be viewed in terms of the type of program and the contractual strategy being considered. The contracts may be 6.3 and 6.4 and may be individual or parallel efforts. If funding availability in terms of dollars and time phasing are sufficient, parallel efforts should be given serious consideration.

AR 1000-1 suggests paralleling the AD effort and "flying off" for the remainder of the program. DDR&E correspondence through channels relative to "Price Limited Prototypes" suggests paralleling the ED effort with production being the prize. Both approaches show merit, and of course, besides funding constraints, the choice could be limited by absence of the AD phase. Also, if the AD program is parallelled, this can place a more stringent problem of control on the manager to keep follow-on costs in line. When dealing with the single contractor approach, the incentive/award fee pool becomes extremely critical.

Determination of when to pursue the parallel approach cannot be arrived at without a great deal of thought. Certain assumptions and a framework can be established, however, and when applied, the results can be used as the decision argument. First, it can be assumed that competing developers with proper incentive will provide a more effective item than would a single developer. The cost of this "increase" in effectiveness is roughly something less than a doubling of the R&D cost. For the approach to be full satisfactory, the additional costs must be offset by savings in investment (production) and through the operating life. If an item has a low estimated R&D costs and is a high volume or high dollar value total procurement, the parallel approach is obviously a viable approach. If, however, the item has a large R&D cost estimate and the projected procurement is small, the parallel approach will not fare too well. Here, a single developer with incentives on ownership costs would be a better approach. Between these two extremes, each program will have to be analyzed on its own merit. The estimator must estimate the potential savings for production and operating costs and weigh this against the increased R&D costs.

The above introduction of "cost of ownership" is a very important factor, and the DTUPC is almost meaningless in the framework of the new acquisition philosophy, if operating costs are not considered. It is true that reliability goals (bands) will be a part of the required performance criteria, but the resultant costs can be as important as the performance. Good showing on the MTBF and MTTR can be partially offset by high repair cost.

The inclusion of cost of ownership criteria does not imply the old Total Package Procurement (TPP) approach for many reasons. Under the "design to" concept each phase is contracted for separately, with the design and development portions using cost plus award fee (CPAF) contracts. Trade-offs in performance and schedule are considered to maintain acceptable costs, and no commitment to full production is made until successful field testing is completed. In proposal evaluation, the Life Cycle Cost (LCC) is not evaluated as a specific value, rather the bidder's proposed approach for minimization of the LCC is evaluated. This approach should address trade-off analysis which are to be made while both the cost of ownership projections and DTUPC are tracked throughout the contract. A general rule should be that a DTUPC should never be used without the incorporation of cost of ownership evaluation requirements.

The incorporation of the DTUPC and cost of ownership requirements must be made extremely clear in the RFP/RFQ. To develop a standard clause for each might be impossible, since all foreseeable situations cannot be predicted. However, "examples" have been described in the AMC Basic Procurement Guidance. So, rather than present another example, an attempt at specifying standards will be followed.

From the initial definition of the DTUPC on page 1 of this paper, critical words are underlined. Reiteration of the words are made here for emphasis and to provide the framework for a solicitation clause on the DTUPC. The words are:

Unit
Goal
Guide
Control
Projected
Production
Economical level of production

These key words can be combined meaningfully into three groups. The first group can be "projected production unit". The second is the goal, guide, and control which implies a system of tracking or traceability. The last is "economical level of production" which can be defined in terms of quantity and time. However, since "schedule" is a parameter that can be traded off for cost, only quantity should appear in the standard clause. Moreover, the "economical level" or quantity is difficult to define precisely if the production facility is not known and the availability of funds is uncertain. The total number to be procured by the Government may also be too small to ever qualify at an "economical level". The quantity, therefore, should be the size of the first contemplated full production contract. Whether this is a "buy-out" during LRIP (or first production) or represents the first production contract after LRIP, should not have too much of an effect on the DTUPC (other than escalation magnitude), but can affect the tracking system desired.

The tracking system to project a unit cost subsequent to an IRIP must be extremely detailed and capable of auditing, since the developer/IRIP contractor may not have to live with these projections if the production contract is competively placed.

An early "rough" estimate of the economic level of production can be made early in the estimating process by dividing the projected BOI or AAO quantity by 5 (representative of 5 years) to obtain a one year production guidance. It can be seen for small BOI/AAO criteria, large complex systems, and other criteria could very easily make this approach invalid and these criteria as well as funding constraints will have to be considered.

Since the DTUPC will be affected by changes in the economy the RFP/RFQ should contain a clear provision for treating economic changes. This can best be done by the incorporation of accepted price indices in the design-to clause. For programs where multiple contract efforts will provide a competing atmosphere, the specific index to use takes on lesser importance, since the competition should tend to bring in production bids on item design costs lower than the DTUPC. When a single contractor is contemplated or when the explicit intent is to design the maximum performance into the target price, the index should be chosen with more care. In such instances, it is recommended that an appropriate combination of the applicable subdivisions of the Wholesale Price Index (WPI) and an Index derived from the Gross Average Hourly Earnings for the applicable categories be developed. This means that consideration must be given to the material/labor ratio of the product as well as the apportionment of different industry sectors or commodities for the material weighting. For apportionment of the labor index the relative ratio of different industry types will have to be considered. The derivation of a composite index should be accomplished through the joint efforts of engineering, production, and cost analysis personnel No one index can be validly applied across the board for USAECOM commodities and programs.

When addressing cost of ownership in the RFP/RFQ, it should be made clear that the intent is to foster continuing trade-off analysis throughout the development program and that recommended changes to reduce design-to costs should entail an exposition of what affects the change has on life cycle cost. Program viability is to constrain "flyaway" cost by the use of the DTUPC, and to minimize total cost of ownership within that contraint. The cost of ownership requirements should be defined in a Work Statement and include the requirements of Life Cycle Cost elements to be considered, the time phasing expeeted, treatment of inflation and economic analysis, treatment of risk and uncertainty, and the timely submissions of reports with complete substantiating rationale.

A time when a DTUPC should not be applied, is on the single contractor approach, where the cost of incorporating the tracking and reporting requirements outweigh the benefits to be gained. Determination of such candidates is nebulous at this time, and will remain so until cost experience is accumulated.

By policy, a DTUPC must be applied on all programs where it is directed by higher headquarters. AMC policy is that all programs with projected PEMA investment of 25 million dollars or more require a DTUPC. Also, a DTUPC may be indirectly required when a command item is being developed to be incorporated in another command's overall system that has a required DTUPC. In this case, an allocated DTUPC will have to be negotiated with the other command or project management office.

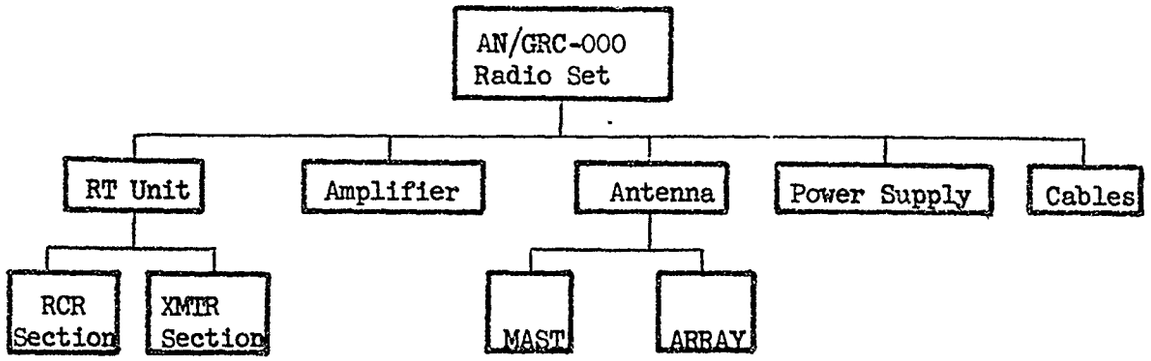
Methods of Developing DTUPC.

There are four general methods of developing the DTUPC, and each one should be considered for each estimate. Some might be better than others, and some may turn out to be the only feasible method, depending upon the state of development in terms of the R&D cycle. Basically, these four methods are:

Cost estimating relationship (CER)
Analogy
Bogey by direction
Industrial engineering

Each of the above methods is accompanied by some degree of error, and for that reason the DTUPC should not initially be viewed as a point estimate, but as a probable range. Once the ranges are developed to satisfaction, a "not to exceed" DTUPC, may be established. The estimated cost range will be applied against a performance range or as stated officially, bands of performance.

The first step in the methodology of developing the DTUPC is to construct, in agreement with the user, a work breakdown structure (WBS) (figure 1) and acceptable bands of performance. This will delineate the scope of the required estimate and preclude, as much as possible, later controversy as to what is and what is not included in the DTUPC. The WBS should be broken out down to the third level of indenture, according to present guidance. This should not prove to be too difficult on a large system. However, on individual equipment programs, which are the prevalent type, in this command, third level indenture may or may not be possible. For example, a manpack radio would require a breakout to the transmitter, receiver, DC to DC converter, power sources, etc., to approach the third level of the WBS. The general type of historical data available, however, may only allow for estimating at the radio level. Now it can be argued that the radio is the third level, as it could be an item making up a forward area net (second level) which is part of an Army area system (first level). This will especially be true where items are being developed specifically in support of defined Project Managed systems. The level of WBS indenture should then be a management decision. Even in cases where the DTUPC estimate is not delineated to lower levels, the contractual criteria should require it. In the contract, the costing out or estimating should also be tracked at lower levels of a WBS.



Example
Work Breakdown Structure

Figure 1.

Cost Estimating Relationship (CER)

Once the WBS has been defined, the situation would be made easier by the availability of CERs for each lower level item. Further, to be ideal, each CER would have to include as its dependent variables all of the performance characteristics represented by the bands of performance. In such a case, the following graphical representation describes the methodology to be used. The "thresholds" shown are the requirements that cannot be violated by the contractor. The "goals" shown are an optional feature that can be used if incentives are to be applied to cost and performance. The increase in the cost threshold over the highest estimate is also, an optional feature and its use or non-use will depend upon the confidence the estimator places in the high estimate, and what the Government feels is the maximum it can pay for the value (performance) desired.

In practically every case, however, the CER will not represent more than two or three of the performance criteria. This will allow the above method to be used on those few criteria. For the remaining performance requirements, it is evident that the development of a cost curve is not possible from the basic CER, and other CERs or methods will have to be used to determine a matching of the performance band limits to the cost band limits. These other methods will include analogy and industrial engineering techniques, and will be addressed later.

The basic CER can be one that is available or one specifically developed to meet the need at hand. Oftentimes, those charged with developing the cost DTUPC, or any estimate, will look to centralized organizations for available CERs, and if none are available will then make "engineering" estimates. This is not the only alternative. The development of a cost DTUPC is the respon-

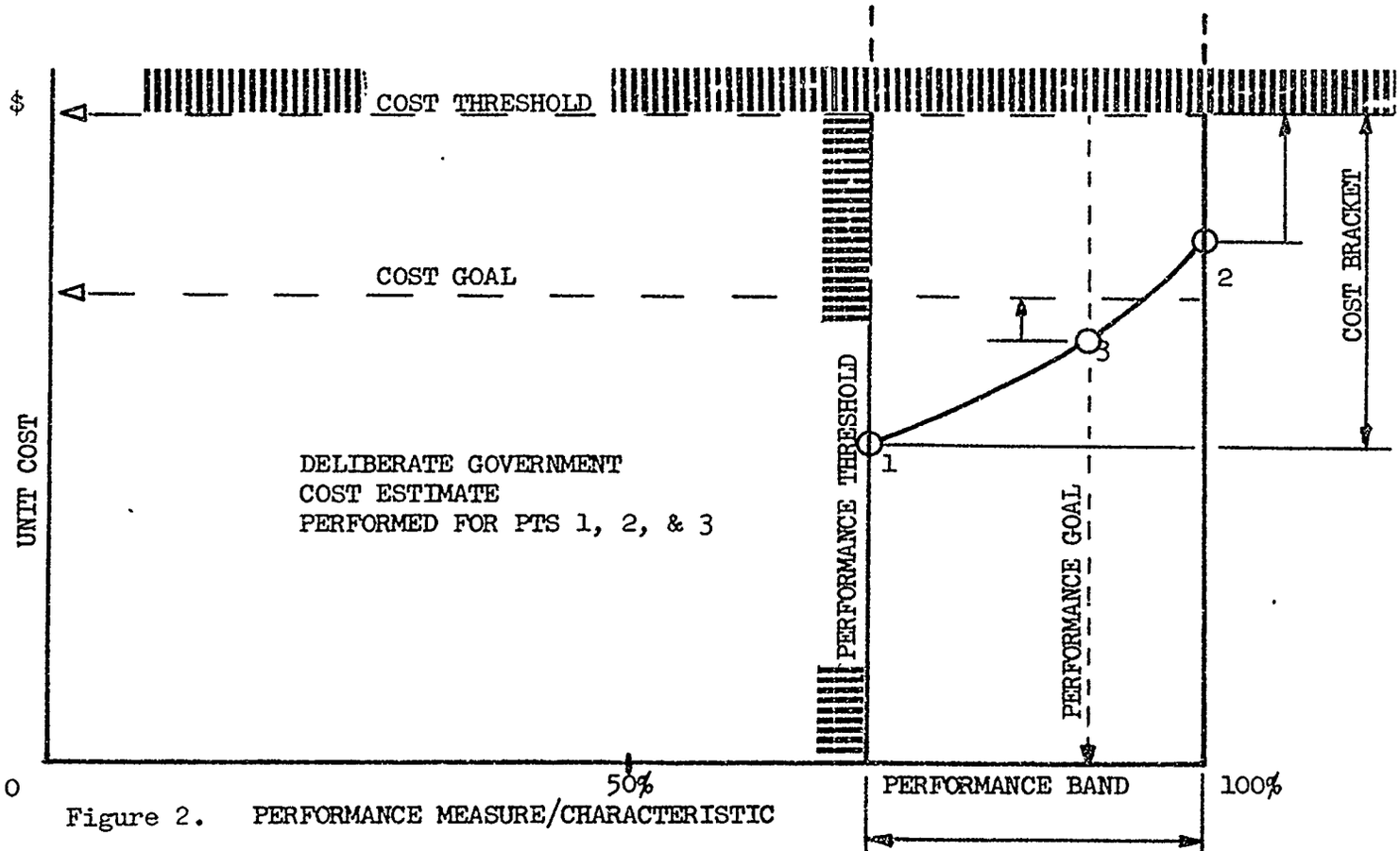


Figure 2. PERFORMANCE MEASURE/CHARACTERISTIC

DISCUSSION: The cost parameters shown above as the goal, threshold, and band should be determined based on a deliberate government cost estimate related to three points within the performance bracket (i.e., at the two extremes and at the performance goal). Point 1 is the cost value estimated to obtain the minimum level of performance and should be regarded as the lower limit of the cost band. Point 2 is the cost value estimated to obtain the upper level of performance and should be regarded as a base from which to establish the cost threshold. Point 3 is the cost value estimated to obtain the level of performance designated as the performance goal and should be regarded as the base from which to establish the cost goal. The line traced out between points 1, 2, and 3 reflects the "best" estimate of cost to achieve the respective levels of performance throughout the performance band.

sibility of the Project Manager, or the proponent of the system/equipment, and this should imply that such assignment of responsibility is made to those most knowledgeable in the specific commodity area. Accordingly, this should indicate that the capability of developing a CER resides predominantly with the proponent. Basically, the CER is a mathematical function relating technical or performance characteristics to cost. The function is a representation of mapping the independent variables (characteristics) to the dependent variable (cost). The most popular technique is linear regression, since computer programs are readily available, and the method provides statistical measures of abberations in the data. More sophisticated techniques such as polynomial regression are also available on a computerized basis. The linear regression programs also allow for extended independent variables, additive strings of the form $aX_1 + bX_2 + cX_3$, etc. Logrithmic transforms can be used to convert a multiplicative, power function such as $aX_1^bX_2^c$ etc., to $\ln a + b\ln X_1 + c\ln X_2$ for solution by linear techniques.

Regression is not the only technique available and indeed might not be the best method, especially when there is little data or the data is tightly grouped. Any mathematical method that will map the variables and describes a relationship can be explored. The critical point is that the cause and result relationship must be logically sound.

Analogy

Estimating costs by analogy to other items is probably the most prevalent methodology used, and is the underlying basis of "engineering judgement". It is also probably the most powerful method if applied in a carefully planned, detailed, and conscientous manner. The problem exists that it is too often applied in a quick, haphazard manner, and has thus received skeptical reception. The absence of statistical tests of significance also make it less palatable to ultimate users of the estimate.

The analogy procedure is used to estimate the cost of the unknown item by comparing it to items that are similar in function, construction, and/or technology. Several item comparisons should be made to strengthen the final estimate. When no analogous items are found for the overall item, the method should be applied at lower WBS levels. Heaviest concentration should be placed on what are felt to be the largest cost contributing elements. Documentation of the entire approach should be very comprehensive in order to instill confidence in the estimate and overcome any preconceived notions of the inadequacy of the analogy approach. The Comptroller's Office has published a paper entitled "Guidelines for Cost Estimation by Analogy" which provides more detailed instruction on this approach.

DTUPC by Direction

It is not inconceivable that a DTUPC might be directed by higher levels of management or by apportionment from a PM's overall system. In such instances, the estimating procedures will have to be reversed. That is, the equipment performance capabilities will have to be estimated for a given item cost. The CER or analogy approach can again be used, however, the results will be explicitly variable in nature in that performance capability in one area will be likely to vary inversely with another area. In other words, trade-offs between performance variables can be made to maintain the given cost. Care must be taken to stay within the individual bounds of the performance criteria covered by the CER or analogy. If none of the possible combinations of performance capabilities estimates are acceptable to the user, a case is implicitly made to either require a review and upward change to the bogey or to initiate a 6.2 (exploratory development) program using the unattainable (at present) DTUPC as a "goal" in developing the necessary componentry.

Industrial Engineering

This method of estimating can be used when the item design is pretty well known or established. Also, it can be used in reinforcing portions of the analogy approach. It is especially useful when a hardware model (6.2 or 6.3) is available and the basic component makeup exists. The greatest difficulty in applying this approach is that the Government is not the producer, and therefore, does not have exact knowledge or control of the manufacturing/fabrication process or subcontracting criteria (make or buy). Not having this knowledge, the estimator is left with the ability to roughly price out the material costs. He cannot, however, estimate with any degree of accuracy, direct labor or overhead costs, since these are dependent upon the manufacturing process and accounting procedures for individual firms. The estimator does not have a priori knowledge of this information. For estimating purposes, however, it might be possible to develop general factors that lump direct labor, burden, and profit together and this factor might then be applied to the material cost estimate. Many people appear to have such "rule-of-thumb" factors in their head, but they are not documented. They should, by all means, be documented to afford credibility.

In developing the estimate from the material list base, it is highly recommended that the estimate be made on the basis of a fairly large quantity of items. Normal industrial practice is to estimate at some "steady state" quantity which would vary from company to company. From this large quantity estimate, an estimated "learning curve" can be applied to determine the cost for other quantities. This procedure will be less sensitive to total dollar cost error than if the "first unit" price is estimated and an estimated learning curve is then applied to that.

Tracking the DTUPC

Placing the estimated DTUPC in the RFQ/RFP or contract does not in itself assure the realization of the desired results. The approach that the prospective contractor proposes to use to estimate, or price out the item throughout the contractual effort is of extreme importance. The RFP and the contractual document should specify in detail the requirements and importance of the tracking procedure to furnish continuing visibility. The Government enjoys no real guarantee that what the developer projects to be the unit production cost can or will be realized on an economic level of production. A follow-on contractual effort for Low Rate Initial Production (LRIP) does not necessarily reflect an economical level of production, even though it will be conducted in a production environment subsequent to the benefits of Producibility Engineering and Planning (PEP) and the results of DTII/OTII testing. The prime purpose of LRIP as stated in Army guidance is to minimize the "exposure to large retrofit problems and costs" by producing a minimum quantity to perform transitional testing (DTIII/OTIII), maintain the contractual program continuity, and prove producibility. The developer may or may not win the full production contracts. However, to proceed along the LRIP route requires the obtaining of a Limited Production (LP) type classification. If the planned program is toward Standard A type classification, the only way at present to assure continuity of first production with the developer is under the provisions of ASPR paragraph 3-108(d) which implies such criteria as complexity. The policy set forth by AR 1000-1 is still to complete production as soon as possible and, therefore, care in production planning must be taken to assure that a proven product is procured under competition as soon as possible. The tracked DTUPC then is a projected estimate and critical attention must therefore be directed at the methods, procedures, and assumptions used in making the projection.

The basic requirements of the contractor's tracking system are uniformity, detail, continuity, and a sound forecasting rationale. Basically, the system is to continually track the progress of finalizing actual costs during the contractual period against the established target. The first step then is to carefully define the target. The contractor should have little difficulty defining the target at least in terms of the first few levels of the WBS, however, care should be taken here. Remember, that the contractor is to investigate trade-off studies that include design, so it might be well to look for a functional WBS rather than a black box type. A functional WBS can always be "rolled up" later into black box summations. An important factor in the breakout of the target is to establish sub-targets that are traceable by the contractor's internal accounting system. Throughout the course of the contract, the accountability of the target computation should be capable of ready and easy audit.

The target(s) and accounting procedure should therefore be closely aligned and correlate on all points. These points include all materials pricing data (vendor data or internal fabrications costs), direct labor rates, and burden rates. Such data should be capable of identification with process categories, such as, manufacturing and assembly, tooling, material, quality control, packaging, purchasing, and production engineering.

The computational procedure for calculating the design-to-cost should be explicitly defined in terms of the above and should provide ready reference for the accoutability of risk by identifying those elements that are firming up with a degree of confidence and those elements that are truly estimates or projections. Although, all the data will be estimated projections until the day procurement is initiated, there should exist an explicit degree of confidence in the various factors. The procedure should further be capable of highlighting those areas where trade-off analysis will have the greatest impact, thus justifying engineering and design effort on those areas.

A further point on the tracking system is that it should be amenable to and express the ability to show status readily. A reporting cycle to the Government of a monthly basis should be a minimum criteria. Proposed item changes requiring Government approval should be capable of being generated with full life cycle as well as target impact readily so that Government decision can be accomplished on a one month turn-around cycle.

Overall, the system should make maximum use of detailed cost rationale such as vendor quotes and make/buy evaluations. It is envisioned that the target estimate rationale will proceed from rough projections early in the contract to more detailed, substantial data toward the end.